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Method and Circuit Arrangement for Controlling a Vehicle

The present invention relates to a method and circuit for controlling a vehicle, wherein the rotation behavior of the individual wheels is measured and evaluated in order to determine the vehicle reference speed, wheel slip, wheel acceleration and other control values. These values are used for proportioning and/or modulating the brake pressure in the wheel brakes of the wheels being controlled and/or an intervention in the engine management.

The methods for controlling a vehicle are designed to stabilize the vehicle in critical situations and to maintain its maneuverability. They are integrated in vehicle-control systems such as anti-lock systems (ABS), traction slip control (TCS) or driving-dynamics control systems (ESP). ABS prevents the wheels from blocking during braking operations. ESP, in its function as an overall system or superior system, ensures that the vehicle, particularly in a curve, does not exhibit instability, which would cause it to swerve sideways.

With the help of TCS, the build-up of brake pressure at the overspeeding drive wheels causes the wheel slip to be reduced to a value appropriate for ensuring the traction and driving stability. This system exists both for two-wheel drive and all-wheel drive vehicles. Besides the term TCS, such terms as „electronic differential lock" (EDS), traction slip control or traction (ASC or ASC+T), or „traction control system (TCS)" also are used. A differentiation should be made between two designs: TCS and brake-TCS. In certain situations TCS throttles the engine torque additionally by intervening in the engine management in order to keep the load on the wheels as low as

possible. Brake-TCS becomes effective exclusively through automatic brake intervention. In the description below, the term „TCS" refers to all feasible traction control systems, i.e., with and without intervention in the engine management.

In the prior art it already has been disclosed that the control response can be improved by detecting the vibrations of the drive train and changing the pressure modulation, e.g. in an active ABS control or active TCS control, in such a way that the wheel vibrations are not additionally increased, but rather dampened by a corresponding counter-phase modulation of the brake pressure in the wheel brakes. A prerequisite for this method is that the oscillations of the drive train and their resonant frequency is recognized.

For this purpose, the vehicle control system basically is designed for usage on roads characterized by an essentially smooth surface and, at least on the sides, an approximately equal friction value. A special problem in controlling a vehicle is a driving situation on a gravel road or a similar road with a higher slip requirement.

Therefore, it is the object of the present invention to disclose a method and circuit for detecting a gravel road or a similar road with a higher slip requirement.

The object according to the invention is solved by a method characterized in that the vibration behavior of the individual wheels on the driven axle is detected and evaluated in order to identify a gravel road or a similar road with a higher slip requirement, and that the driving situation on a gravel road is considered to have been identified and/or a corresponding control function of the vehicle control system is activated only when the wheel acceleration exceeds a specified wheel acceleration limit value on at least two wheels and when these two wheels exhibit a certain vibration behavior.

According to the present invention, the term „gravel road" refers to roads characterized by irregularities and loose subsoil.

These types of road conditions lead to an increased slip requirement, with the term „increased slip requirement" within the scope of the present invention meaning that the longitudinal force (force in the radial direction of the tire to transmit the drive forces and, in the event of a braking operation, the brake forces) reaches its maximum with higher wheel-slip values. The slip requirement of a gravel road actually is higher than the slip requirement on packed snow.

An essential aspect of the method for controlling a vehicle according to the present invention is that, in addition to detecting the rotation behavior of the wheels, the vibration behavior of the individual wheels, especially the wheels on the driven axle, is detected and evaluated. The driving situation of a gravel road is then considered to have been identified and/or a corresponding control function of the vehicle control system is activated only when the wheel acceleration is greater than a specified limit value and when the wheels exhibit a certain vibration behavior. This means when certain vibration conditions characteristic of a gravel road are satisfied.

According to the present invention, the wheel acceleration limit value preferably is specified within a range of 1g to 2g, in particular about 1.5.

According to the present invention, a prerequisite for identifying a gravel road is that a specified period of the vibrations on at least two driven wheels is detected, with such period lying within a specified period range, preferably within a range of 30 msec. to 150 msec, or the detection of a specified period of the vibrations on at least two driven wheels, which reaches a specified limit value, preferably about 50 msec.

The period of the vibrations advantageously should be detected over a certain period of time in order to definitely detect a period. This period of time preferably should be 30 msec. to 150 msec., in particular about 50 msec. This means that generally the detection of a period of a vibration is sufficient for detecting a gravel road.

According to the present invention, a gravel road is then considered to have been identified and/or a corresponding control function of the vehicle control system is only activated when the driven wheels exhibit a specified traction slip, in particular a traction slip in the range of 0 km/h to 50 km/h.

In the method according to the present invention, a gravel road is then considered to have been identified and/or a corresponding control function of the vehicle control system is only activated when the calculated or estimated vehicle reference speed falls below a specified vehicle speed limit value, which advantageously lies within a range of 60 km/h to 100 km/h and preferably is about 80 km/h.

According to the present invention, a gravel road is then considered to have been identified and/or a corresponding control function of the vehicle control system is only activated when the above-mentioned conditions for a gravel road were identified for both wheels on one side of the vehicle and/or one vehicle axle of a vehicle with all-wheel drive, or when the above-mentioned conditions for a gravel road were identified for both wheels on the driven axle of a vehicle with one driven axle.

Within the meaning of the invention, the term „vehicle with all-wheel drive“ comprises both vehicles with at least four permanently driven wheels on at least two driven axles as well as vehicles driven primarily by one axle, in which a second

axle can be added when necessary. This can occur manually or automatically, for example with the aid of a viscous clutch.

When a gravel road has been identified, especially according to the method described above, an engine control threshold is increased, as disclosed in the present invention, preferably to a value within a range of 2 km/h to 10 km/h, especially preferred about 3 km/h, and/or a brake control threshold is increased, preferably within a range of 0 km/h to 10 km/h, especially advantageously about 3 km/h.

In this context, the term „engine control threshold" means the wheel slip that needs to be set by the engine control to achieve the best possible compromise between traction and driving stability, in particular TCS engine control. Within the meaning of the invention, the term „brake control threshold" refers to the wheel slip that needs to be set by the brake control to achieve the best possible compromise between traction and driving stability, in particular TCS brake control.

According to the present invention, the brake control threshold is increased only when certain driving situations are identified, e.g. highly overspeeding wheels, e.g. in terrain with large wheel-load fluctuations or under ì-split conditions.

Furthermore, the object of the invention is solved by means of a circuit for controlling a vehicle, such as an anti-lock system (ABS), traction slip control system (TCS) or driving-dynamics control system (ESP), which is characterized in that it exhibits an identification circuit for identifying a gravel road or a similar road with a higher slip requirement. A detection circuit for detecting the vibration behavior of the individual wheels is associated with such identification circuit. The output of the detection circuit is connected to the input of an evaluation circuit in order to evaluate the detected vibration behavior. The identification circuit

exhibits an integrator and signal generator to generate a signal when a certain vibration behavior of the wheels typical for gravel roads is detected over a period of time predefined by the integrator with the help of the evaluation of the evaluation circuit.

The detection circuit preferably exhibits comparators for the wheel acceleration as well as extreme-value detectors to detect the vibration behavior of the individual wheels.

In accordance with an embodiment of the present invention, the circuit is characterized in that a calculating circuit is associated with the identification circuit in order to calculate a vehicle reference speed on the basis of measured values, and the output of the calculating circuit is connected to an input of a first comparator which serves to compare the calculated vehicle reference speed with a predefined limit value, and this first comparator is connected via an output to an input of the evaluating circuit, and the evaluating circuit compares the detected vibration behavior of the individual wheels, in particular the period of a vibration, with the specified limit values; that the identification circuit exhibits a second comparator for comparing the wheel acceleration with a wheel acceleration limit value, a third comparator for comparing the vibration behavior of the individual wheels to one another, and a fourth comparator for comparing the traction slip of the wheels with a specified limit value; and that an output of the signal generator is connected to an input of a device used for intervening in the brake control and/or engine control when an appropriate signal for an identified driving situation on a gravel road is emitted.

The invention will be explained in more detail on the basis of two flow diagrams (Figure 1 and Figure 2) and a block diagram (Figure 3) below.

Figure 1 shows a flow diagram of an embodiment of the method for detecting the wheel vibration behavior for a gravel road on one wheel according to the invention.

Figure 2 shows a flow diagram of an embodiment of the method for detecting a gravel road according to the invention.

Figure 3 is a block diagram of an embodiment of the circuit for detecting a gravel road according to the invention.

As shown in Figure 1, wheel acceleration by means of query 2 is required as a basic condition for detecting the vibration behavior for a gravel road on a wheel at the beginning after the start (step 1), with such wheel acceleration lying above a wheel acceleration limit value (B_{lim}), e.g. above 1g. Then it is checked whether the individual wheels exhibit vibration behavior characteristic of a gravel road. For this purpose - if the wheel acceleration limit value (B_{lim}) is exceeded - the period of time between the maximum points of a period of vibration is determined and query steps 3 and 4 check whether the period of vibrations on the wheel lie within a specified range that is defined by an upper limit value (T_1) (step 3) and a lower limit value (T_2) (step 4). The interval defined by the upper limit value (T_1) and lower limit value (T_2) is set depending on the dynamics and vibration behavior of the drive train of the vehicle and the road surface to be detected. When these conditions are satisfied, an integrator associated with the wheel being observed is incremented in a specified period of time. For this purpose, a counter associated with the wheel concerned is increased by 1 respectively in step 5. If this is not the case, then the counter is reduced by 1 respectively in step 6. The value can be decremented to zero (0) in this way. If, on the other hand, the counter exceeds a threshold value ($COUNTER_{lim}$) (step 7), the conditions for a gravel road have been detected for the wheel concerned (step 8). In the other case, if the conditions of steps 2 or 3 or 4 or 7 were not

satisfied, the vibration conditions for a gravel road will not be considered to have been identified on the wheel (step 9).

After the detection or non-detection of vibration conditions for a gravel road on one wheel (step 8 or 9) shown in Figure 1, the driving situation of a gravel road is determined advantageously according to the flow diagram in Figure 2 (beginning step 10). For this purpose, the vibration behavior determined on the individual wheels is compared. If the vibration behavior for a gravel road was identified on at least two wheels (step 11) and if the traction slip lies within a specified range, i.e. below a first limit value (S_1), e.g. 50 km/h (step 12), and above a second limit value (S_2), e.g. 0 km/h (step 13), the query continues to step 14. In step 14 it is queried whether the vehicle reference speed (V_{ref}) lies below a speed threshold (V_{lim}), e.g. below 80 km/h. If this applies, the driving situation of a gravel road will be considered to have been identified and a corresponding control function of the vehicle control system can be activated. For example, this could mean increasing the engine control threshold and/or the brake control threshold (step 15). In all other cases, if the conditions of the queries in steps 11 or 12 or 13 or 14 are not satisfied, a reset to the main program of the control system, e.g. an TCS, occurs (step 16).

According to the invention, all previously described steps can be realized advantageously by means of corresponding program steps of a software program or a sub-program within a vehicle control system, in particular traction slip control (TCS).

However, the steps also can be realized with the aid of a circuit arrangement. The block diagram in Figure 3 illustrates such a circuit arrangement, which, by way of example, shows the essential electric/electronic components of an embodiment for detecting a gravel road.

An essential element of the invention is the identification circuit (20). A detection circuit (21) for detecting the vibration behavior on the individual wheels is associated with the identification circuit (20), and the output (22) of the detection circuit (21) is connected to an input (23) of an evaluation circuit (24) for evaluating the detected vibration behavior. The identification circuit (20) exhibits an integrator (25) and signal generator (26) for generating a signal when a certain vibration behavior typical for gravel roads is detected on the wheels over a period of time predefined by the integrator (25) with the help of the evaluation of the evaluation circuit (23). In addition, a calculating circuit (27) for calculating a vehicle reference speed (V_{ref}) on the basis of measured values is associated with the identification circuit (20). An output (28) of the calculating circuit (27) is connected to an input (29) of a first comparator (30), which serves to compare the calculated vehicle reference speed (V_{ref}) with a specified limit value (V_{lim}); and this first comparator (30) is connected via an output (31) to an input (32) of the evaluation circuit (23), which compares the detected vibration behavior of the individual wheels, in particular the period of a vibration, with specified limit values (T_1, T_2). The identification circuit (20) exhibits a second comparator (33) used for comparing the wheel acceleration with a wheel acceleration limit value (B_{lim}), a third comparator (34) for comparing the vibration behavior of the individual wheels to one another, and a fourth comparator (35) for comparing the traction slip of the wheels with a specified limit value (S_1, S_2). The signal generator (26) is connected via an output (36) to an input (37) of a device (38) used for intervening in the brake control and/or engine control when an appropriate signal for an identified driving situation on a gravel road is emitted.